

IV. CHEMICAL RELEASE AND TRANSFER PROFILE

This section is designed to provide background information on the pollutant releases that are reported by this industry. The best source of comparative pollutant release information is the Toxic Release Inventory System (TRI). Pursuant to the Emergency Planning and Community Right-to-Know Act, TRI includes self-reported facility release and transfer data for over 600 toxic chemicals. Facilities within SIC Codes 20-39 (manufacturing industries) that have more than 10 employees, and that are above weight-based reporting thresholds are required to report TRI on-site releases and off-site transfers. TRI is not specific to the chemical industry. The information presented within the sector notebooks is derived from the most recently available (1993) TRI reporting year (which then included 316 chemicals), and focuses primarily on the on-site releases reported by each sector. Because TRI requires consistent reporting regardless of sector, it is an excellent tool for drawing comparisons across industries.

Although this sector notebook does not present historical information regarding TRI chemical releases, please note that in general, toxic chemical releases across all industries have been declining. In fact, according to the 1993 Toxic Release Inventory Data Book, reported releases dropped by 42.7 percent between 1988 and 1993. Although on-site releases have decreased, the total amount of reported toxic waste has not declined because the amount of toxic chemicals transferred off-site has increased. Transfers have increased from 3.7 billion pounds in 1991 to 4.7 billion pounds in 1993. Better management practices have led to increases in off-site transfers of toxic chemicals for recycling. More detailed information can be obtained from EPA's annual Toxics Release Inventory Public Data Release book (which is available through the EPCRA Hotline at 800-535-0202), or directly from the Toxic Release Inventory System database (for user support call 202-260-1531).

Wherever possible, the sector notebooks present TRI data as the primary indicator of chemical release within each industrial category. TRI data provide

the type, amount and media receptor of each chemical released or transferred. When other sources of pollutant release data have been obtained, these data have been included to augment the TRI information.

TRI Data Limitations

The reader should keep in mind the following limitations regarding TRI data. Within some sectors, the majority of facilities are not subject to TRI reporting because they are not considered manufacturing industries, or because they are below TRI reporting thresholds. Examples are the mining, dry cleaning, printing, and transportation equipment cleaning sectors. For these sectors, release information from other sources has been included.

The reader should also be aware that TRI "pounds released" data presented within the notebooks is not equivalent to a "risk" ranking for each industry. Weighting each pound of release equally does not factor in the relative toxicity of each chemical that is released. The Agency is in the process of developing an approach to assign toxicological weightings to each chemical released so that one can differentiate between pollutants with significant differences in toxicity. As a preliminary indicator of the environmental impact of the industry's most commonly released chemicals, the notebook briefly summarizes the toxicological properties of the top chemicals (by weight) reported by each industry.

Definitions Associated With Section IV Data Tables

General Definitions

SIC Code -- is the Standard Industrial Classification (SIC) is a statistical classification standard used for all establishment-based Federal economic statistics. The SIC codes facilitate comparisons between facility and industry data.

TRI Facilities -- are manufacturing facilities that have 10 or more full-time employees and are above established chemical throughput thresholds.

Manufacturing facilities are defined as facilities in Standard Industrial Classification primary codes 20-39. Facilities must submit estimates for all chemicals that are on the EPA's defined list and are above throughput thresholds.

Data Table Column Heading Definitions

The following definitions are based upon standard definitions developed by EPA's Toxic Release Inventory Program. The categories below represent the possible pollutant destinations that can be reported.

RELEASES -- are an on-site discharge of a toxic chemical to the environment. This includes emissions to the air, discharges to bodies of water, releases at the facility to land, as well as contained disposal into underground injection wells.

Releases to Air (Point and Fugitive Air Emissions) -- include all air emissions from industry activity. Point emission occur through confined air streams as found in stacks, ducts, or pipes. Fugitive emissions include losses from equipment leaks, or evaporative losses from impoundments, spills, or leaks.

Releases to Water (Surface Water Discharges) -- encompass any releases going directly to streams, rivers, lakes, oceans, or other bodies of water. Any estimates for stormwater runoff and non-point losses must also be included.

Releases to Land -- includes disposal of toxic chemicals in waste to on-site landfills, land treated or incorporation into soil, surface impoundments, spills, leaks, or waste piles. These activities must occur within the facility's boundaries for inclusion in this category.

Underground Injection -- is a contained release of a fluid into a subsurface well for the purpose of waste disposal.

TRANSFERS -- is a transfer of toxic chemicals in wastes to a facility that is geographically or physically separate from the facility reporting

under TRI. The quantities reported represent a movement of the chemical away from the reporting facility. Except for off-site transfers for disposal, these quantities do not necessarily represent entry of the chemical into the environment.

Transfers to POTWs -- are wastewaters transferred through pipes or sewers to a publicly owned treatments works (POTW). Treatment and chemical removal depend on the chemical's nature and treatment methods used. Chemicals not treated or destroyed by the POTW are generally released to surface waters or landfilled within the sludge.

Transfers to Recycling -- are sent off-site for the purposes of regenerating or recovering still valuable materials. Once these chemicals have been recycled, they may be returned to the originating facility or sold commercially.

Transfers to Energy Recovery -- are wastes combusted off-site in industrial furnaces for energy recovery. Treatment of a chemical by incineration is not considered to be energy recovery.

Transfers to Treatment -- are wastes moved off-site for either neutralization, incineration, biological destruction, or physical separation. In some cases, the chemicals are not destroyed but prepared for further waste management.

Transfers to Disposal -- are wastes taken to another facility for disposal generally as a release to land or as an injection underground.

IV.A. EPA Toxic Release Inventory for the Inorganic Chemical Industry

The 1993 TRI data presented in Exhibits 11 and 12 for inorganic chemicals manufacturing covers 555 facilities. These facilities listed SIC 281 (industrial inorganic chemicals) as a primary SIC code. The Bureau of Census identified 1,429 facilities manufacturing inorganic chemicals. More than half of these facilities, however, have fewer than 20 employees, many of which are likely to be below the TRI reporting thresholds of employment

(TRI reporting threshold is greater than 10 employees) and/or chemical use and, therefore, are not required to report to TRI.

According to TRI data, in 1993 the inorganic chemical industry released (discharged to the air, water, or land without treatment) and transferred (shipped off-site) a total of 250 million pounds of 112 different chemical toxic chemicals. This represents about 10 percent of the TRI releases and transfers of the chemical manufacturing industry and about three percent of the total releases and transfers of all manufacturers that year. In comparison, the organic chemical industry (SIC 286) produced 438 million pounds that year, almost twice that of the inorganic chemical industry.⁵⁵

The chemical industry's releases have been declining in recent years. Between 1988 and 1993 TRI emissions from chemical companies (all those categorized within SIC 28, not just inorganic chemical manufacturers) to air, land, and water were reduced 44 percent, which is slightly above the average for all manufacturing sectors reporting to TRI.⁵⁶

Because the chemical industry (SIC 28) has historically released more TRI chemicals than any other industry, the EPA has worked to improve environmental performance within this sector. This has been done through a combination of enforcement actions, regulatory requirements, pollution prevention projects, and voluntary programs (e.g. 33/50). In addition, the chemical industry has focused on reducing pollutant releases. For example, the Chemical Manufacturers Association's (CMA's) Responsible Care initiative is intended to reduce or eximinate chemical manufacturers' waste. All 184 members of the CMA, firms that account for the majority of U.S. chemical industry sales and earnings, are required to participate in the program. Participation involves demonstrating a commitment to the program's mandate of continuous improvement in environment, health, and safety. In June of 1994, the CMA approved the use of a third-party verification of management plans to meet these objectives.

Exhibits 11 and 12 present the number and volumes of chemicals released and transferred by inorganic chemical facilities, respectively. The frequency with which chemicals are reported by facilities within a sector is one indication of the diversity of operations and processes. Many of the TRI chemicals are released or transferred by only a small number of facilities which indicates a wide diversity of production processes, particularly for specialty inorganics -- over 70 percent of the 110 chemicals reported are released or transferred by fewer than 10 facilities.

The inorganic chemical industry releases 69 percent of its total TRI poundage to the water (including 67 percent to underground injection and two percent to surface waters), 14 percent to the air, and 17 percent to the land. This release profile differs from other TRI industries which average approximately 30 percent to the water, 59 percent to air, and 10 percent to land. Examining the inorganic chemical industry's TRI reported toxic chemical releases highlights the likely origins of the large water releases for the industry (Exhibit 11).

As presented in Exhibit 11, on-site underground injection of essentially one chemical, hydrochloric acid, accounts for the largest portion, 55 percent, of the inorganic chemical industry's total releases and transfers as reported in TRI. Only five facilities of the 555 identified facilities reported releasing hydrochloric acid through underground injection. Two of these facilities accounted for over 85 percent of the total hydrochloric acid injected to the subsurface, or 42 percent of the inorganic chemical industry's total releases and transfers. Land disposal accounted for the next largest amount, 17 percent, of the industry's total releases. The largest single chemical released to the air by the inorganic chemical industry, carbonyl sulfide, is only emitted by eleven facilities manufacturing certain inorganic pigments.

Discharges to POTWs accounted for 43 percent of the industry's total transfers of TRI chemicals. Ammonia, hydrochloric acid, and sulfuric acid account for over 66 percent of the 70 million

pounds transferred off-site. Finally, approximately 22 million pounds, accounting for 31 percent of the total, are transferred off-site for treatment (Exhibit 12).

The TRI database contains a detailed compilation of self-reported, facility-specific chemical releases. The top reporting facilities for this sector are listed below. Facilities that have reported only the SIC codes covered under this notebook appear on the first list. The second list contains additional facilities that have reported the SIC code covered within this report, and one or more SIC codes that are not within the scope of this notebook. Therefore, the second list includes facilities that conduct multiple operations -- some that are under the scope of this notebook, and some that are not. Currently, the facility-level data do not allow pollutant releases to be broken apart by industrial process.

Exhibit 13: Top 10 TRI Releasing Inorganic Chemicals Facilities^b		
Rank	Facility	Total TRI Releases in Pounds
1	Du Pont Delisle Plant - Pass Christian, MS	58,875,734
2	Du Pont Johnsonville Plant - New Johnsonville, TN	51,215,700
3	Cabot Corp. Cab-O-Sil Div. - Tuscola, IL	13,926,440
4	American Chrome & Chemicals Inc. - Corpus Christi, TX	12,113,360
5	Occidental Chemical Corp. - Castle Hayne, NC	6,705,795
6	Chemetals Inc. - New Johnsonville, TN	5,684,893
7	Kaiser Aluminum & Chemical Corp. - Mulberry, FL	4,876,348
8	Kerr-McGee Chemical Corp. - Henderson, NV	2,333,175
9	SCM Chemicals Americas Plant II - Ashtabula, OH	2,238,400
10	Louisiana Pigment Co. L.P. - Westlake, LA	1,465,753
Source: U.S. EPA, Toxics Release Inventory Database, 1993.		

^b Being included on this list does not mean that the release is associated with non-compliance with environmental laws.

Exhibit 14: Top 10 TRI Releasing Facilities Reporting Inorganic Chemical SIC Codes to TRI^c			
Rank	SIC Codes Reported in TRI	Facility	Total TRI Releases in Pounds
1	2819, 2873, 2874	IMC-Agrico Co., Faustina Plant - Saint James, LA	127,912,967
2	2819, 2869	Cytec Industries, Inc., Fortier Plant - Westwego, LA	120,149,724
3	2819, 2874	IMC-Agrico Co., Uncle Sam Plant - Uncle Sam, LA	61,807,180
4	2816	Du Pont Delisle Plant - Pass Christian, MS	58,875,734
5	2816	Du Pont Johnsonville Plant - New Johnsonville, TN	51,215,700
6	2819, 2823	Courtaulds Fibers, Inc. - Axis, AL	42,658,865
7	2819, 2869, 2841, 2879	Monsanto Co. - Alvin, TX	40,517,095
8	2819, 2869, 2865	Sterling Chemicals, Inc. - Texas City, TX	24,709,135
9	2819, 2873, 2874	Arcadian Fertilizer L.P. - Geismar, LA	22,672,961
10	2812, 2813, 2869	Vulcan Chemicals - Wichita, KS	17,406,218
Source: U.S. EPA, Toxics Release Inventory Database, 1993.			

IV.B. Summary of Selected Chemicals Released

The brief descriptions provided below were taken from the *1993 Toxics Release Inventory Public Data Release* (EPA, 1994), and the Hazardous Substances Data Bank (HSDB), accessed via TOXNET. TOXNET is a computer system run by the National Library of Medicine. It includes a number of toxicological databases managed by EPA, the National Cancer Institute, and the National Institute for Occupational Safety and Health.^d HSDB contains chemical-specific information on manufacturing and use, chemical and physical properties, safety and handling, toxicity and biomedical effects, pharmacology, environmental fate and exposure

^c Being included on this list does not mean that the release is associated with non-compliance with environmental laws.

^d Databases included in TOXNET are: CCRIS (Chemical Carcinogenesis Research Information System), DART (Developmental and Reproductive Toxicity Database), DBIR (Directory of Biotechnology Information Resources), EMICBACK (Environmental Mutagen Information Center Backfile), GENE-TOX (Genetic Toxicology), HSDB (Hazardous Substances Data Bank), IRIS (Integrated Risk Information System), RTECS (Registry of Toxic Effects of Chemical Substances), and TRI (Toxic Chemical Release Inventory).

potential, exposure standards and regulations, monitoring and analysis methods, and additional references. The information contained below is based upon exposure assumptions that have been conducted using standard scientific procedures. The effects listed below must be taken in context of these exposure assumptions that are more fully explained within the full chemical profiles in HSDB. For more information on TOXNET, contact the TOXNET help line at 800-231-3766.

Hydrochloric Acid (CAS: 7647-01-1)

Sources. Hydrochloric acid is one of the highest volume chemicals produced by the inorganic chemical industry. Some of its more common uses are as a pickling liquor and metal cleaner in the iron and steel industry, as an activator of petroleum wells, as a boiler scale remover, and as a neutralizer of caustic waste streams. The largest release of hydrochloric acid by the inorganic chemical industry is in the form of underground injection of spent hydrochloric acid used to manufacture chlorosulfonic acid and other products.⁵⁷

Toxicity. Hydrochloric acid is primarily a concern in its aerosol form. Acid aerosols have been implicated in causing and exacerbating a variety of respiratory ailments. Dermal exposure and ingestion of highly concentrated hydrochloric acid can result in corrosivity.

Ecologically, accidental releases of solution forms of hydrochloric acid may adversely affect aquatic life by including a transient lowering of the pH (i.e., increasing the acidity) of surface waters.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Releases of hydrochloric acid to surface waters and soils will be neutralized to an extent due to the buffering capacities of both systems. The extent of these reactions will depend on the characteristics of the specific environment.

Physical Properties. Concentrated hydrochloric acid is highly corrosive.

Chromium and Chromium Compounds (CAS: 7440-47-3; 20-06-4)

Sources. Chrome pigments, chromates, chromic acid, chromium salts, and other inorganic chromium compounds are some of the larger volume products of the inorganic chemicals industry. Chrome is used as a plating element for metal and plastics to prevent corrosion, and as a constituent of

certain steels and inorganic pigments. Most chromium wastes released to the environment by the inorganic chemicals industry are land disposed in the form of chromium containing sludges.

Toxicity. Although the naturally-occurring form of chromium metal has very low toxicity, chromium from industrial emissions is highly toxic due to strong oxidation characteristics and cell membrane permeability. The majority of the effects detailed below are based on Chromium VI (an isomer that is more toxic than Cr III). Exposure to chromium metal and insoluble chromium salts affects the respiratory system. Inhalation exposure to chromium and chromium salts may cause severe irritation of the upper respiratory tract and scarring of lung tissue. Dermal exposure to chromium and chromium salts can also cause sensitive dermatitis and skin ulcers.

Ecologically, although chromium is present in small quantities in all soils and plants, it is toxic to plants at higher soil concentrations (i.e., 0.2 to 0.4 percent in soil).

Carcinogenicity. Different sources disagree on the carcinogenicity of chromium. Although an increased incidence in lung cancer among workers in the chromate-producing industry has been reported, data are inadequate to confirm that chromium is a human carcinogen. Other sources consider chromium VI to be a known human carcinogen based on inhalation exposure.

Environmental Fate. Chromium is a non-volatile metal with very low solubility in water. If applied to land, most chromium remains in the upper five centimeters of soil. Most chromium in surface waters is present in particulate form as sediment. Airborne chromium particles are relatively unreactive and are removed from the air through wet and dry deposition. The precipitated chromium from the air enters surface water or soil. Chromium bioaccumulates in plants and animals, with an observed bioaccumulation factor of 1,000,000 in snails.

Carbonyl Sulfide (CAS: 463-58-1)

Sources. Carbonyl sulfide is the largest volume chemical released to the air by the inorganic chemicals industry. Carbonyl sulfide is primarily generated by a relatively small number of facilities hydrolyzing ammonium or potassium thiocyanate during the manufacturing of inorganic pigments and dyes.⁵⁸

Toxicity. Exposure to low to moderate concentrations of carbonyl sulfide causes eye and skin irritation and adverse central nervous system effects

such as giddiness, headache, vertigo, amnesia, confusion, and unconsciousness. If ingested, gastrointestinal effects include profuse salivation, nausea, vomiting and diarrhea. Moderate carbonyl sulfide poisoning also causes rapid breathing and heartbeat, sweating, weakness, and muscle cramps. Exposure to very high concentrations of carbonyl sulfide causes sudden collapse, unconsciousness, and death from sudden respiratory paralysis. Recovery from sublethal exposure is slow, but generally complete. Degradation products of carbonyl sulfide (especially hydrogen sulfide) can result in toxic symptoms and death.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. If released to soil or surface waters, carbonyl sulfide will rapidly volatilize. It is not expected to adsorb to soil sediments or organic matter nor is it expected to bioconcentrate in fish and aquatic organisms. Carbonyl sulfide is hydrolyzed in water to carbon dioxide and hydrogen sulfide. Carbonyl sulfide is expected to have a long residence time in the atmosphere. Atmospheric removal of carbonyl sulfide may occur by slow reactions with other gases, and may also occur through adsorption by plants and soil microbes.

Manganese and Manganese Compounds (CAS: 7439-96-5; 20-12-2)

Sources. Manganese is both a product and chemical intermediate of the inorganic chemical industry. Manganese is used as a purifying and scavenging agent in metal production, as an intermediate in aluminum production and as a constituent of non-ferrous alloys to improve corrosion resistance and hardness.⁵⁹

Toxicity. There is currently no evidence that human exposure to manganese at levels commonly observed in ambient atmosphere results in adverse health effects. However, recent EPA review of the fuel additive MMT (methylcyclopentadienyl manganese tricarbonyl) concluded that use of MMT in gasoline could lead to ambient exposures to manganese at a level sufficient to cause adverse neurological effects in humans.

Chronic manganese poisoning bears some similarity to chronic lead poisoning. Occurring via inhalation of manganese dust or fumes, it primarily involves the central nervous system. Early symptoms include languor, speech disturbances, sleepiness, and cramping and weakness in legs. A stolid mask-like appearance of face, emotional disturbances such as absolute detachment broken by uncontrollable laughter, euphoria, and a spastic gait with a tendency to fall while walking are seen in more

advanced cases. Chronic manganese poisoning is reversible if treated early and exposure stopped. Populations at greatest risk of manganese toxicity are the very young and those with iron deficiencies.

Ecologically, although manganese is an essential nutrient for both plants and animals, in excessive concentrations manganese inhibits plant growth.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Manganese is an essential nutrient for plants and animals. As such, manganese accumulates in the top layers of soil or surface water sediments and cycles between the soil and living organisms. It occurs mainly as a solid under environmental conditions, though may also be transported in the atmosphere as a vapor or dust

Ammonia (CAS: 7664-41-7)

Sources. Ammonia is used in many chemical manufacturing processes and is the building block for all synthetic nitrogen products. Its prevalence and its volatile and water soluble characteristics allow it to be readily released to the air and water. In the inorganic chemical manufacturing industry, ammonia can be either a feedstock or a by-product. Some of the more common inorganic chemical industry processes using or producing ammonia include the manufacturing of: ammonium chloride, ammonium hydroxide, ammonium thiosulfate, ammonium nitrate, hydrazine, and hydrogen cyanide.

Toxicity. Anhydrous ammonia is irritating to the skin, eyes, nose, throat, and upper respiratory system. Ecologically, ammonia is a source of nitrogen (an essential element for aquatic plant growth), and may therefore contribute to eutrophication of standing or slow-moving surface water, particularly in nitrogen-limited waters such as the Chesapeake Bay. In addition, aqueous ammonia is moderately toxic to aquatic organisms.

Carcinogenicity. There is currently no evidence to suggest that this chemical is carcinogenic.

Environmental Fate. Ammonia combines with sulfate ions in the atmosphere and is washed out by rainfall, resulting in rapid return of ammonia to the soil and surface waters. Ammonia is a central compound in the environmental cycling of nitrogen. Ammonia in lakes, rivers, and streams is converted to nitrate.

Physical Properties. Ammonia is a corrosive and severely irritating gas with a pungent odor.

IV.C. Other Data Sources

In addition to chemicals covered under TRI, many other chemicals are released. For example, the EPA Office of Air Quality Planning and Standards has compiled air pollutant emission factors for determining the total air emissions of priority pollutants (e.g., VOCs, SO_x, NO_x, CO, particulates) from many chemical industry sources.

The EPA Office of Air's Aerometric Information Retrieval System (AIRS) contains a wide range of information related to stationary sources of air pollution, including the emissions of a number of air pollutants which may be of concern within a particular industry. With the exception of volatile organic compounds (VOCs), there is little overlap with the TRI chemicals reported above. Exhibit 15 summarizes annual releases of carbon monoxide (CO), nitrogen dioxide (NO₂), particulate matter of 10 microns or less (PM₁₀), total particulate (PT), sulfur dioxide (SO₂) and volatile organic compounds (VOCs).

Exhibit 15: Pollutant Releases (short tons/year)						
Industry Sector	CO	NO₂	PM₁₀	PT	SO₂	VOC
Metal Mining	5,391	28,583	39,359	140,052	84,222	1,283
Nonmetal Mining	4,525	28,804	59,305	167,948	24,129	1,736
Lumber and Wood Production	123,756	42,658	14,135	63,761	9,419	41,423
Furniture and Fixtures	2,069	2,981	2,165	3,178	1,606	59,426
Pulp and Paper	624,291	394,448	35,579	113,571	541,002	96,875
Printing	8,463	4,915	399	1,031	1,728	101,537
Inorganic Chemicals	166,147	103,575	4,107	39,062	182,189	52,091
Organic Chemicals	146,947	236,826	26,493	44,860	132,459	201,888
Petroleum Refining	419,311	380,641	18,787	36,877	648,155	369,058
Rubber and Misc. Plastics	2,090	11,914	2,407	5,355	29,364	140,741
Stone, Clay and Concrete	58,043	338,482	74,623	171,853	339,216	30,262
Iron and Steel	1,518,642	138,985	42,368	83,017	238,268	82,292
Nonferrous Metals	448,758	55,658	20,074	22,490	373,007	27,375
Fabricated Metals	3,851	16,424	1,185	3,136	4,019	102,186
Computer and Office Equipment	24	0	0	0	0	0
Electronics and Other Electrical Equipment and Components	367	1,129	207	293	453	4,854
Motor Vehicles, Bodies, Parts and Accessories	35,303	23,725	2,406	12,853	25,462	101,275
Dry Cleaning	101	179	3	28	152	7,310
Source: U.S. EPA Office of Air and Radiation, AIRS Database, May 1995.						

IV.D. Comparison of Toxic Release Inventory Between Selected Industries

The following information is presented as a comparison of pollutant release and transfer data across industrial categories. It is provided to give a general sense as to the relative scale of releases and transfers within each sector profiled under this project. Please note that the following figure and table do not contain releases and transfers for industrial categories that are not included in this project, and thus cannot be used to draw conclusions regarding the total release and transfer amounts that are reported to TRI. Similar information is available within the annual TRI Public Data Release Book.

Exhibit 16 is a graphical representation of a summary of the 1993 TRI data for the inorganic chemicals industry and the other sectors profiled in separate notebooks. The bar graph presents the total TRI releases and total transfers on the left axis and the triangle points show the average releases per facility on the right axis. Industry sectors are presented in the order of increasing total TRI releases. The graph is based on the data shown in Exhibit 17 and is meant to facilitate comparisons between the relative amounts of releases, transfers, and releases per facility both within and between these sectors. The reader should note, however, that differences in the proportion of facilities captured by TRI exist between industry sectors. This can be a factor of poor SIC matching and relative differences in the number of facilities reporting to TRI from the various sectors. In the case of the inorganic chemicals, the 1993 TRI data presented here covers 555 facilities. These facilities listed SIC 2812-2819 (inorganic chemicals) as a primary SIC code.

SIC Range	Industry Sector	SIC Range	Industry Sector	SIC Range	Industry Sector
36	Electronic Equipment and Components	2911	Petroleum Refining	286	Organic Chemical Mfg.
24	Lumber and Wood Products	34	Fabricated Metals	26	Pulp and Paper
32	Stone, Clay, and Concrete	371	Motor Vehicles, Bodies, Parts, and Accessories	281	Inorganic Chemical Mfg.
27	Printing	331	Iron and Steel	333,334	Nonferrous Metals
25	Wood Furniture and Fixtures	30	Rubber and Misc. Plastics		

V. POLLUTION PREVENTION OPPORTUNITIES

The best way to reduce pollution is to prevent it in the first place. Some companies have creatively implemented pollution prevention techniques that improve efficiency and increase profits while at the same time minimize environmental impacts. This can be done in many ways such as reducing material inputs, re-engineering processes to reuse by-products, improving management practices, and employing substitute toxic chemicals. Some smaller facilities are able to actually get below regulatory thresholds just by reducing pollutant releases through aggressive pollution prevention policies.

In order to encourage these approaches, this section provides both general and company-specific descriptions of some pollution prevention advances that have been implemented within the inorganic chemical manufacturing industry. While the list is not exhaustive, it does provide core information that can be used as the starting point for facilities interested in beginning their own pollution prevention projects. When possible, this section provides information from real activities that can, or are being implemented by this sector -- including a discussion of associated costs, time frames, and expected rates of return. This section also provides the context (in terms of type of industry and/or type of process affected) in which the pollution prevention technique can effectively be used.

There have been numerous cases where the chemical industry has simultaneously reduced pollutant outputs and operating costs through pollution prevention techniques. In the inorganic chemicals manufacturing sector, however, economically viable pollution prevention opportunities are not as easily identified as in other sectors. The relatively small size and limited resources of a typical inorganic chemical facility limits the number

of feasible pollution prevention options. The limited resources available to the industry eliminates many pollution prevention options that require significant capital expenditures such as process modifications and process redesign. In addition, the inorganic chemicals industry's products are primarily commodity chemicals for which the manufacturing processes have been developed over many years. Commodity chemical manufacturers redesign their processes infrequently so that redesign of the reaction process or equipment is unlikely in the short term. In addition, the industry's process equipment has been amortized over long periods of time making cost-effective process equipment improvements scarce. As a result, pollution prevention in the inorganic chemicals industry is somewhat restricted to the less costly options, such as minor process modifications, operational changes, raw material substitutions, and recycling.

Pollution prevention in the chemical industry is process specific. As such it is difficult to generalize about the relative merits of different pollution prevention strategies. The age and size of the facility, and the type and number of its processes will determine the most effective pollution prevention strategy. Brief descriptions of some of the more widespread, general pollution prevention techniques found to be effective at inorganic chemicals facilities are provided below. Many of these pollution prevention opportunities can be applied to the petrochemical industry as a whole due to the many similar processes found throughout the industry. It should be noted that many of the ideas identified below as pollution prevention opportunities, aimed at reducing wastes and reducing materials use, have been carried out by the chemicals manufacturing industry for many years as the primary means of improving process efficiencies and increasing profits.

In chlor-alkali production, pollution prevention options have been demonstrated for both the mercury cell and diaphragm cell processes; however, the best opportunity to reduce pollutant outputs, conserve energy, and reduce costs in the chlor-alkali industry are in the conversion to the membrane cell process. In terms of energy consumption, the membrane cell process uses only about 77 percent of that of the mercury cell process and about 90 percent of that of the diaphragm cell process. The membrane cell process also generates significantly less airborne and waterborne pollutants and solid wastes (see Section III.B. - Raw Material Inputs and Pollution Outputs).

Substitute raw materials. The substitution or elimination of some of the raw materials used in the manufacturing of inorganic chemicals can result in substantial waste reductions and cost savings. Because impurities in the

feed stream can be a major contributor to waste generation, one of the most common substitutions is to use a higher purity feedstock. This can be accomplished either by working with suppliers to get a higher quality feed or by installing purification equipment. Raw materials can also be substituted with less toxic and less water soluble materials to reduce water contamination, and with less volatile materials to reduce fugitive emissions. Sometimes certain raw materials can be eliminated all together. The need for raw materials that end up as wastes should be reexamined to determine if raw materials can be eliminated by modifying the process and improving control.

Improve reactor efficiencies. Since the chemical products are primarily created inside the process reactor, it can be the primary source for waste (off-spec) materials. One of the most important parameters dictating the reactor efficiency is the quality of mixing. A number of techniques can be used to improve mixing, such as installing baffles in the reactor, a higher rpm motor for the agitator, a different mixing blade design, multiple impellers, and pump recirculation. The method used to introduce feed to the reactor can also have an effect on the quality of mixing. A feed distributor can be added to equalize residence time through the reactor, and feed streams can be added at a point in time closer to the ideal reactant concentration. This will avoid secondary reactions which form unwanted by-products.

Improve catalyst. The catalyst plays a critical role in the effectiveness of chemical conversion in the reactor. Alternative chemical makeups and physical characteristics can lead to substantial improvements in the effectiveness and life of a catalyst. Different catalysts can also eliminate by-product formation. Noble metal catalysts can replace heavy metal catalysts to eliminate wastewater contaminated with heavy metals. The consumption of catalysts can be reduced by using a more active form and emissions and effluents generated during catalyst activation can be eliminated by obtaining the catalyst in the active form.

Optimize processes. Process changes that optimize reactions and raw materials use can reduce waste generation and releases. Many larger facilities are using computer controlled systems which analyze the process continuously and respond more quickly and accurately than manual control systems. These systems are often capable of automatic startups, shutdowns, and product changeover which can bring the process to stable conditions quickly, minimizing the generation of off-spec wastes. Other process optimization techniques include: equalizing the reactor and storage tank vent lines during batch filling to minimize vent gas losses; sequencing the addition of reactants and reagents to optimize yields and lower

emissions; and optimizing sequences to minimize washing operations and cross-contamination of subsequent batches.

Reduce heat exchanger wastes and inefficiencies. Heat exchangers are often the source of significant off-spec product wastes generated by overheating the product closest to the tube walls. The best way to reduce off-spec product from overheating is by reducing the heat exchanger tube wall temperature. This can be accomplished through a number of techniques which do not reduce the overall heat transferred such as: reducing the tube wall temperature and increasing the effective surface area of the heat exchanger; using staged heating by first heating with waste heat, then low pressure steam, followed by superheated high pressure steam; monitor and prevent fouling of the heat exchanger tubes so that lower temperature heat sources can be used; using noncorroding tubes which will foul less quickly than tubes that corrode.

Improve wastewater treatment and recycling. A large portion of the inorganic chemical industry's pollutants leave the facilities as wastewater or wastewater treatment system sludge. Improved treatment and minimization of wastewater are effective pollution prevention opportunities that often do not require significant changes to the industrial processes. Modern wastewater treatment technologies such as ion exchange, electrolytic cells, reverse osmosis, and improved distillation, evaporation, and dewatering can often be added to existing treatment systems. Wastewater streams containing acids or metals can be concentrated enough to be sold commercially as a product by slightly altering the manufacturing process, adding processing steps, and segregating wastewater streams. Furthermore, many wastewater streams can be reused within the same or different processes, significantly reducing discharges to the wastewater treatment system. An ion exchange system installed in a mercury cell chlor-alkali plant reduced mercury by 99 percent in the facility's effluent. An inorganic chemicals plant making photochemistry solution generated a wastewater containing silver. Electrolytic cells were installed that recovered 98 percent of the silver and an evaporator was added that concentrated the remaining liquid for disposal resulting in a 90 percent reduction in waste volume.

Prevent leaks and spills. The elimination of sources of leaks and spills can be a very cost effective pollution prevention opportunity. Leaks and spills can be prevented by installing seamless pumps and other "leakless" components, maintaining a preventative maintenance program, and maintaining a leak detection program.

Improve inventory management and storage. Good inventory management can reduce the generation of wastes by preventing materials from exceeding their shelf life, preventing materials from being left over or not needed, and reducing the likelihood of accidental releases of stored material. Designating a materials storage area, limiting traffic through the area, and giving one person the responsibility to maintain and distribute materials can reduce materials use, and the contamination and dispersal of materials.

Exhibit 18 summarizes the above pollution prevention opportunities and provides additional examples provided by the Chemical Manufacturers Association.

Exhibit 18: Process/Product Modifications Create Pollution Prevention Opportunities

Area	Potential Problem	Possible Approach
<p>Byproducts Coproducts</p> <p><i>Quantity and Quality</i></p> <p><i>Uses and Outlets</i></p>	<ul style="list-style-type: none"> ■ Process inefficiencies result in the generation of undesired by-products and co-products. Inefficiencies will require larger volumes of raw materials and result in additional secondary products. Inefficiencies can also increase fugitive emissions and wastes generated through material handling. ■ By-products and co-products are not fully utilized, generating material or waste that must be managed. 	<ul style="list-style-type: none"> ■ Increase product yield to reduce by-product and co-product generation and raw material requirements. ■ Identify uses and develop a sales outlet. Collect information necessary to firm up a purchase commitment such as minimum quality criteria, maximum impurity levels that can be tolerated, and performance criteria.

<p>Catalysts</p> <p><i>Composition</i></p> <p><i>Preparation and Handling</i></p>	<ul style="list-style-type: none"> ■ The presence of heavy metals in catalysts can result in contaminated process wastewater from catalyst handling and separation. These wastes may require special treatment and disposal procedures or facilities. Heavy metals can be inhibitory or toxic to biological wastewater treatment units. Sludge from wastewater treatment units may be classified as hazardous due to heavy metals content. Heavy metals generally exhibit low toxicity thresholds in aquatic environments and may bioaccumulate. ■ Emissions or effluents are generated with catalyst activation or regeneration. ■ Catalyst attrition and carry over into product requires de-ashing facilities which are a likely source of wastewater and solid waste. 	<ul style="list-style-type: none"> ■ Catalysts comprised of noble metals, because of their cost, are generally recycled by both onsite and offsite reclaimers. ■ Obtain catalyst in the active form. ■ Provide in situ activation with appropriate processing/activation facilities. ■ Develop a more robust catalyst or support.
Exhibit 18 (cont.): Process/Product Modifications Create Pollution Prevention Ops.		
Area	Potential Problem	Possible Approach

<p>Catalysts (cont'd)</p> <p><i>Preparation and Handling (cont')</i></p> <p><i>Effectiveness</i></p>	<ul style="list-style-type: none"> ■ Catalyst is spent and needs to be replaced. ■ Pyrophoric catalyst needs to be kept wet, resulting in liquid contaminated with metals. ■ Short catalyst life. ■ Catalyzed reaction has by-product formation, incomplete conversion and less-than-perfect yield. ■ Catalyzed reaction has by-product formation, incomplete conversion and less-than perfect yield. 	<ul style="list-style-type: none"> ■ In situ regeneration eliminates unloading/loading emissions and effluents versus offsite regeneration or disposal. ■ Use a nonpyrophoric catalyst. Minimize amount of water required to handle and store safely. ■ Study and identify catalyst deactivation mechanisms. Avoid conditions which promote thermal or chemical deactivation. By extending catalyst life, emissions and effluents associated with catalyst handling and regeneration can be reduced. ■ Reduce catalyst consumption with a more active form. A higher concentration of active ingredient or increased surface area can reduce catalyst loadings. ■ Use a more selective catalyst which will reduce the yield of undesired by-products. ■ Improve reactor mixing/contacting to increase catalyst effectiveness. ■ Develop a thorough understanding of reaction to allow optimization of reactor design. Include in the optimization, catalyst consumption and by-product yield.
<p>Intermediate Products</p> <p><i>Quantity and Quality</i></p>	<ul style="list-style-type: none"> ■ Intermediate reaction products or chemical species, including trace levels of toxic constituents, may contribute to process waste under both normal and upset conditions. ■ Intermediates may contain toxic constituents or have characteristics that are harmful to the environment. 	<ul style="list-style-type: none"> ■ Modify reaction sequence to reduce amount or change composition of intermediates. ■ Modify reaction sequence to change intermediate properties. ■ Use equipment design and process control to reduce releases.
<p>Exhibit 18 (cont.): Process/Product Modifications Create Pollution Prevention Ops.</p>		
<p>Area</p>	<p>Potential Problem</p>	<p>Possible Approach</p>

Process Conditions/ Configuration		
<p><i>Temperature</i></p>	<ul style="list-style-type: none"> ■ High heat exchange tube temperatures cause thermal cracking/decomposition of many chemicals. These lower molecular weight by-products are a source of "light ends" and fugitive emissions. High localized temperature gives rise to polymerization of reactive monomers, resulting in "heavies" or "tars." such materials can foul heat exchange equipment or plug fixed-bed reactors, thereby requiring costly equipment cleaning and production outage. ■ Higher operating temperatures imply "heat input" usually via combustion which generates emissions. ■ Heat sources such as furnaces and boilers are a source of combustion emissions. ■ Vapor pressure increases with increasing temperature. Loading/unloading, tankage and fugitive emissions generally increase with increasing vapor pressure. 	<ul style="list-style-type: none"> ■ Select operating temperatures at or near ambient temperature whenever possible. ■ Use lower pressure steam to lower temperatures. ■ Use intermediate exchangers to avoid contact with furnace tubes and walls. ■ Use staged heating to minimize product degradation and unwanted side reactions. ■ Use a super heat of high-pressure steam in place of furnace. ■ Monitor exchanger fouling to correlate process conditions which increase fouling, avoid conditions which rapidly foul exchangers. ■ Use online tube cleaning technologies to keep tube surfaces clean to increase heat transfer. ■ Use scraped wall exchangers in viscous service. ■ Use falling film reboiler, pumped recirculation reboiler or high-flux tubes. ■ Explore heat integration opportunities (e.g., use waste heat to preheat materials and reduce the amount of combustion required.) ■ Use thermocompressor to upgrade low-pressure steam to avoid the need for additional boilers and furnaces. ■ If possible, cool materials before sending to storage. ■ Use hot process streams to reheat feeds.

Exhibit 18 (cont.): Process/Product Modifications Create Pollution Prevention Ops.

Area	Potential Problem	Possible Approach
<p>Process Conditions/ Configuration (cont'd)</p> <p><i>Temperature (cont'd)</i></p> <p><i>Pressure</i></p> <p><i>Corrosive Environment</i></p>	<ul style="list-style-type: none"> ■ Water solubility of most chemicals increases with increasing temperature. ■ Fugitive emissions from equipment. ■ Seal leakage potential due to pressure differential. ■ Gas solubility increases with higher pressures. ■ Material contamination occurs from corrosion products. Equipment failures result in spills, leaks, and increased maintenance costs. ■ Increased waste generation due to addition of corrosion inhibitors or neutralization. 	<ul style="list-style-type: none"> ■ Add vent condensers to recover vapors in storage tanks or process. ■ Add closed dome loading with vapor recovery condensers. ■ Use lower temperature (vacuum processing). ■ Equipment operating in vacuum service is not a source of fugitives; however, leaks into the process require control when system is degassed. ■ Minimize operating pressure. ■ Determine whether gases can be recovered, compressed, and reused or require controls. ■ Improve metallurgy or provide coating or lining. ■ Neutralize corrosivity of materials contacting equipment. ■ Use corrosion inhibitors. ■ Improve metallurgy or provide coating or lining. ■ Improve metallurgy or provide coating or lining or operate in a less corrosive environment.

<i>Batch vs. Continuous Operations</i>	<ul style="list-style-type: none"> ■ Vent gas lost during batch fill. ■ Waste generated by cleaning/purging of process equipment between production batches. 	<ul style="list-style-type: none"> ■ Equalize reactor and storage tank vent lines. ■ Recover vapors through condenser, adsorber, etc. ■ Use materials with low viscosity. Minimize equipment roughness.
--	--	--

Exhibit 18 (cont.): Process/Product Modifications Create Pollution Prevention Ops.

Area	Potential Problem	Possible Approach
<p>Process Conditions/ Configuration (cont'd)</p> <p><i>Batch vs. Continuous Operations (cont'd)</i></p> <p><i>Process Operation/Design</i></p>	<ul style="list-style-type: none"> ■ Process inefficiencies lower yield and increase emissions. ■ Continuous process fugitive emissions and waste increase over time due to equipment failure through a lack of maintenance between turnarounds. ■ Numerous processing steps create wastes and opportunities for errors. ■ Nonreactant materials (solvents, absorbents, etc.) create wastes. Each chemical (including water) employed within the process introduces additional potential waste sources; the composition generated wastes also tends to become more complex. 	<ul style="list-style-type: none"> ■ Optimize product manufacturing sequence to minimize washing operations and cross-contamination of subsequent batches. ■ Sequence addition of reactants and reagents to optimize yields and lower emissions. ■ Design facility to readily allow maintenance so as to avoid unexpected equipment failure and resultant release. ■ Keep it simple. Make sure all operations are necessary. More operations and complexity only tend to increase potential emission and waste sources. ■ Evaluate unit operation or technologies (e.g., separation) that do not require the addition of solvents or other nonreactant chemicals.

	<ul style="list-style-type: none"> ■ High conversion with low yield results in wastes. 	<ul style="list-style-type: none"> ■ Recycle operations generally improve overall use of raw materials and chemicals, thereby increasing the yield of desired products while at the same time reducing the generation of wastes. A case-in-point is to operate at a lower conversion per reaction cycle by reducing catalyst consumption, temperature, or residence time. Many times, this can result in a higher selectivity to desired products. The net effect upon recycle of unreacted reagents is an increase in product yield, while at the same time reducing the quantities of spent catalyst and less desirable by-products.
Exhibit 18 (cont.): Process/Product Modifications Create Pollution Prevention Ops.		
Area	Potential Problem	Possible Approach
Process Conditions/ Configuration (cont'd) <i>Process Operation/Design</i>	<ul style="list-style-type: none"> ■ Non-regenerative treatment systems result in increased waste versus regenerative systems. 	<ul style="list-style-type: none"> ■ Regenerative fixed bed treating or desiccant operation (e.g., aluminum oxide, silica, activated carbon, molecular sieves, etc.) will generate less quantities of solid or liquid waste than nonregenerative units (e.g., calcium chloride or activated clay). With regenerative units though, emissions during bed activation and regeneration can be significant. Further, side reactions during activation/regeneration can give rise to problematic pollutants.

Product <i>Process Chemistry</i> <i>Product Formulation</i>	<ul style="list-style-type: none"> ■ Insufficient R&D into alternative reaction pathways may miss pollution opportunities such as reducing waste or eliminating a hazardous constituent. ■ Product based on end-use performance may have undesirable environmental impacts or use raw materials or components that generate excessive or hazardous wastes. 	<ul style="list-style-type: none"> ■ R&D during process conception and laboratory studies should thoroughly investigate alternatives in process chemistry that affect pollution prevention. ■ Reformulate products by substituting different material or using a mixture of individual chemicals that meet end-use performance specifications.
Raw Materials <i>Purity</i>	<ul style="list-style-type: none"> ■ Impurities may produce unwanted by-products and waste. Toxic impurities, even in trace amounts, can make a waste hazardous and therefore subject to strict and costly regulation. ■ Excessive impurities may require more processing and equipment to meet product specifications, increasing costs and potential for fugitive emissions, leaks, and spills. 	<ul style="list-style-type: none"> ■ Use higher purity materials. ■ Purify materials before use and reuse if practical. ■ Use inhibitors to prevent side reactions. ■ Achieve balance between feed purity, processing steps, product quality, and waste generation.

Exhibit 18 (cont.): Process/Product Modifications Create Pollution Prevention Ops.

Area	Potential Problem	Possible Approach
Raw Materials (cont'd) <i>Purity (cont'd)</i>	<ul style="list-style-type: none"> ■ Specifying a purity greater than needed by the process increases costs and can generate more waste generation by the supplier. ■ Impurities in clean air can increase inert purges. ■ Impurities may poison catalyst prematurely resulting in increased wastes due to yield loss and more frequent catalyst replacement. 	<ul style="list-style-type: none"> ■ Specify a purity no greater than what the process needs. ■ Use pure oxygen. ■ Install guard beds to protect catalysts.

<i>Vapor Pressure</i>	<ul style="list-style-type: none">■ Higher vapor pressures increase fugitive emissions in material handling and storage.■ High vapor pressure with low odor threshold materials can cause nuisance odors.	<ul style="list-style-type: none">■ Use material with lower vapor pressure.■ Use materials with lower vapor pressure and higher odor threshold.
<i>Water Solubility</i>	<ul style="list-style-type: none">■ Toxic or nonbiodegradable materials that are water soluble may affect wastewater treatment operation, efficiency, and cost.■ Higher solubility may increase potential for surface and groundwater contamination and may require more careful spill prevention, containment, and cleanup (SPCC) plans.■ Higher solubility may increase potential for storm water contamination in open areas.■ Process wastewater associated with water washing or hydrocarbon/water phase separation will be impacted by containment solubility in water. Appropriate wastewater treatment will be impacted.	<ul style="list-style-type: none">■ Use less toxic or more biodegradable materials.■ Use less soluble materials.■ Use less soluble materials.■ Prevent direct contact with storm water by diking or covering areas.■ Minimize water usage.■ Reuse wash water.■ Determine optimum process conditions for phase separation.■ Evaluate alternative separation technologies (coalescers, membranes, distillation, etc.)

Exhibit 18 (cont.): Process/Product Modifications Create Pollution Prevention Ops.

Area	Potential Problem	Possible Approach
Raw Materials (cont'd)		
<i>Toxicity</i>	<ul style="list-style-type: none"> Community and worker safety and health concerns result from routine and nonroutine emissions. Emissions sources include vents, equipment leaks, wastewater emissions, emergency pressure relief, etc. Surges or higher than normal continuous levels of toxic materials can shock or miss wastewater biological treatment systems resulting in possible fines and possible toxicity in the receiving water. 	<ul style="list-style-type: none"> Use less toxic materials. Reduce exposure through equipment design and process control. Use systems which are passive for emergency containment of toxic releases. Use less toxic material. Reduce spills, leaks, and upset conditions through equipment and process control. Consider effect of chemicals on biological treatment; provide unit pretreatment or diversion capacity to remove toxicity. Install surge capacity for flow and concentration equalization.
<i>Regulatory</i>	<ul style="list-style-type: none"> Hazardous or toxic materials are stringently regulated. They may require enhanced control and monitoring; increased compliance issues and paperwork for permits and record keeping; stricter control for handling, shipping, and disposal; higher sampling and analytical costs; and increased health and safety costs. 	<ul style="list-style-type: none"> Use materials which are less toxic or hazardous. Use better equipment and process design to minimize or control releases; in some cases, meeting certain regulatory criteria will exempt a system from permitting or other regulatory requirements.
<i>Form of Supply</i>	<ul style="list-style-type: none"> Small containers increase shipping frequency which increases chances of material releases and waste residues from shipping containers (including wash waters). Nonreturnable containers may increase waste. 	<ul style="list-style-type: none"> Use bulk supply, ship by pipeline, or use "jumbo" drums or sacks. In some cases, product may be shipped out in the same containers the material supply was shipped in without washing. Use returnable shipping containers or drums.
<i>Handling and Storage</i>	<ul style="list-style-type: none"> Physical state (solid, liquid, gaseous) may raise unique environmental, safety, and health issues with unloading operations and transfer to process equipment. 	<ul style="list-style-type: none"> Use equipment and controls appropriate to the type of materials to control releases.

Exhibit 18 (cont.): Process/Product Modifications Create Pollution Prevention Ops.

Area	Potential Problem	Possible Approach
Raw Materials (cont'd) <i>Handling and Storage (cont'd)</i>	<ul style="list-style-type: none"> Large inventories can lead to spills, inherent safety issues and material expiration. 	<ul style="list-style-type: none"> Minimize inventory by utilizing just-in-time delivery.
Waste Streams <i>Quantity and Quality</i> <i>Composition</i> <i>Properties</i> <i>Disposal</i>	<ul style="list-style-type: none"> Characteristics and sources of waste streams are unknown. Wastes are generated as part of the process. Hazardous or toxic constituents are found in waste streams. Examples are: sulfides, heavy metals, halogenated hydrocarbons, and polynuclear aromatics. Environmental fate and waste properties are not known or understood. Ability to treat and manage hazardous and toxic waste unknown or limited. 	<ul style="list-style-type: none"> Document sources and quantities of waste streams prior to pollution prevention assessment. Determine what changes in process conditions would lower waste generation of toxicity. Determine if wastes can be recycled back into the process. Evaluate whether different process conditions, routes, or reagent chemicals (e.g., solvent catalysts) can be substituted or changed to reduce or eliminate hazardous or toxic compounds. Evaluate waste characteristics using the following type properties: corrosivity, ignitability, reactivity, BTU content (energy recovery), biodegradability, aquatic toxicity, and bioaccumulation potential of the waste and of its degradable products, and whether it is a solid, liquid, or gas. Consider and evaluate all onsite and offsite recycle, reuse, treatment, and disposal options available. Determine availability of facilities to treat or manage wastes generated.

Source: Chemical Manufacturers Association. *Designing Pollution Prevention into the Process, Research, Development and Engineering*.

Exhibit 19: Modifications to Equipment Can Also Prevent Pollution			
Equipment	Potential Environment Problem	Possible Approach	
		Design Related	Operational Related
Compressors, blowers, fans	<ul style="list-style-type: none"> ▪ Shaft seal leaks ▪ Piston rod seal leaks ▪ Vent streams 	<ul style="list-style-type: none"> ▪ Seal-less designs (diaphragmatic, hermetic or magnetics) ▪ Design for low emissions (internal balancing, double inlet, gland eductors) ▪ Shaft seal designs (carbon rings, double mechanical seals, buffered seals) ▪ Double seal with barrier fluid vented to control device 	<ul style="list-style-type: none"> ▪ Preventive maintenance program
Concrete pads, floors, sumps	<ul style="list-style-type: none"> ▪ Leaks to groundwater 	<ul style="list-style-type: none"> ▪ Water stops ▪ Embedded metal plates ▪ Epoxy sealing ▪ Other impervious sealing 	<ul style="list-style-type: none"> ▪ Reduce unnecessary purges, transfers, and sampling ▪ Use drip pans where necessary
Controls	<ul style="list-style-type: none"> ▪ Shutdowns and Start-ups generate waste and releases 	<ul style="list-style-type: none"> ▪ Improve on-line controls ▪ On-line instrumentation ▪ Automatic start-up and shutdown ▪ On-line vibration analysis ▪ Use "consensus" systems (e.g., shutdown trip requires two out of three affirmative responses) 	<ul style="list-style-type: none"> ▪ Continuous versus batch ▪ Optimize on-line run time ▪ Optimize shutdown interlock inspection frequency ▪ Identify safety and environment critical instruments and equipment
Distillation	<ul style="list-style-type: none"> ▪ Impurities remain in process streams 	<ul style="list-style-type: none"> ▪ Increase reflux ratio ▪ Add section to column ▪ Column intervals ▪ Change feed tray 	<ul style="list-style-type: none"> ▪ Change column operating conditions <ul style="list-style-type: none"> - reflux ratio - feed tray - temperature - pressure - etc.

Exhibit 19 (cont.): Modifications to Equipment Can Also Prevent Pollution			
Equipment	Potential Environment Problem	Possible Approach	
		Design Related	Operational Related
Distillation (cont'd)	<ul style="list-style-type: none"> Impurities remain in process streams (cont'd) Large amounts of contaminated water condensate from stream stripping 	<ul style="list-style-type: none"> Insulate to prevent heat loss Preheat column feed Increase vapor line size to lower pressure drop Use reboilers or inert gas stripping agents 	<ul style="list-style-type: none"> Clean column to reduce fouling Use higher temperature steam
General manufacturing equipment areas	<ul style="list-style-type: none"> Contaminated rainwater Contaminated sprinkler and fire water Leaks and emissions during cleaning 	<ul style="list-style-type: none"> Provide roof over process facilities Segregate process sewer from storm sewer (diking) Hard-pipe process streams to process sewer Seal floors Drain to sump Route to waste treatment Design for cleaning Design for minimum rinsing Design for minimum sludge Provide vapor enclosure Drain to process 	<ul style="list-style-type: none"> Return samples to process Monitor stormwater discharge Use drip pans for maintenance activities Rinse to sump Reuse cleaning solutions

Exhibit 19 (cont.): Modifications to Equipment Can Also Prevent Pollution			
Equipment	Potential Environment Problem	Possible Approach	
		Design Related	Operational Related
Heat exchangers	<ul style="list-style-type: none"> ■ Increased waste due to high localized temperatures 	<ul style="list-style-type: none"> ■ Use intermediate exchangers to avoid contact with furnace tubes and walls ■ Use staged heating to minimize product degradation and unwanted side reactions. (waste heat >>low pressure steam >>high pressure steam) ■ Use scraped wall exchangers in viscous service ■ Using falling film reboiler, piped recirculation reboiler or high-flux tubes ■ Use lowest pressure steam possible ■ Use welded tubes or double tube sheets with inert purge. Mount vertically 	<ul style="list-style-type: none"> ■ Select operating temperatures at or near ambient temperature when-ever possible. These are generally most desirable from a pollution prevention standpoint ■ Use lower pressure steam to lower temperatures ■ Monitor exchanger fouling to correlate process conditions which increase fouling, avoid conditions which rapidly foul exchangers ■ Use on-line tube cleaning techniques to keep tube surfaces clean ■ Monitor for leaks
Piping	<ul style="list-style-type: none"> ■ Contaminated materials due to tubes leaking at tube sheets ■ Furnace emissions ■ Leaks to groundwater Fugitive emissions 	<ul style="list-style-type: none"> ■ Use super heat of high-pressure steam in place of a furnace ■ Design equipment layout so as to minimize pipe run length ■ Eliminate underground piping or design for cathodic protection if necessary to install piping underground ■ Use welded fittings ■ Reduce number of flanges and valves 	<ul style="list-style-type: none"> ■ Monitor for corrosion and erosion ■ Paint to prevent external corrosion

Exhibit 19 (cont.): Modifications to Equipment Can Also Prevent Pollution			
Equipment	Potential Environment Problem	Possible Approach	
		Design Related	Operational Related
Piping (cont'd)	<ul style="list-style-type: none"> Leaks to groundwater Fugitive emissions (cont'd) Releases when cleaning or purging lines 	<ul style="list-style-type: none"> Use all welded pipe Use secondary containment Use spiral-wound gaskets Use plugs and double valves for open end lines Change metallurgy Use lined pipe Use "pigs" for cleaning Slope to low point drain Use heat tracing and insulation to prevent freezing Install equalizer lines 	<ul style="list-style-type: none"> Flush to product storage tank
Pumps	<ul style="list-style-type: none"> Fugitive emissions from shaft seal leaks Fugitive emissions from shaft seal leaks Residual "heel" of liquid during pump maintenance 	<ul style="list-style-type: none"> Mechanical seal in lieu of packing Double mechanical seal with inert barrier fluid Double machined seal with barrier fluid vented to control device Seal-less pump (canned motor magnetic drive) Vertical pump Use pressure transfer to eliminate pump Low point drain on pump casing 	<ul style="list-style-type: none"> Seal installation practices Monitor for leaks Flush casing to process sewer for treatment

Exhibit 19 (cont.): Modifications to Equipment Can Also Prevent Pollution			
Equipment	Potential Environment Problem	Possible Approach	
		Design Related	Operational Related
Pumps (cont'd)	<ul style="list-style-type: none"> Injection of seal flush fluid into process stream 	<ul style="list-style-type: none"> Use double mechanical seal with inert barrier fluid where practical 	<ul style="list-style-type: none"> Increase the mean time between pump failures by: <ul style="list-style-type: none"> - selecting proper seal material; - aligning well; - reducing pipe-induced stress; - maintaining seal lubrication
Reactors	<ul style="list-style-type: none"> Poor conversion or performance due to inadequate mixing Waste by-product formation 	<ul style="list-style-type: none"> Static mixing Add baffles Change impellers Add horsepower Add distributor Provide separate reactor for converting recycle streams to usable products 	<ul style="list-style-type: none"> Add ingredients with optimum sequence Allow proper head space in reactor to enhance vortex effect Optimize reaction conditions (temperature, pressure, etc.)
Relief Valve	<ul style="list-style-type: none"> Leaks Fugitive emissions Discharge to environment from over pressure Frequent relief 	<ul style="list-style-type: none"> Provide upstream rupture disc Vent to control or recovery device Pump discharges to suction of pump Thermal relief to tanks Avoid discharge to roof areas to prevent contamination of rainwater Use pilot operated relief valve Increase margin between design and operating pressure 	<ul style="list-style-type: none"> Monitor for leaks and for control efficiency Monitor for leaks Reduce operating pressure Review system performance

Exhibit 19 (cont.): Modifications to Equipment Can Also Prevent Pollution			
Equipment	Potential Environment Problem	Possible Approach	
		Design Related	Operational Related
Sampling	<ul style="list-style-type: none"> Waste generation due to sampling (disposal, containers, leaks, fugitives, etc.) 	<ul style="list-style-type: none"> On line in situ analyzers System for return to process Closed loop Drain to sump 	<ul style="list-style-type: none"> Reduce number and size of samples required Sample at the lowest possible temperature Cool before sampling
Tanks	<ul style="list-style-type: none"> Tank breathing and working losses Leak to groundwater Large waste heel 	<ul style="list-style-type: none"> Cool materials before storage Insulate tanks Vent to control device (flare, condenser, etc.) Vapor balancing Floating roof Floating roof Higher design pressure All aboveground (situated so bottom can routinely be checked for leaks) Secondary containment Improve corrosion resistance Design for 100 percent de-inventory 	<ul style="list-style-type: none"> Optimize storage conditions to reduce losses Monitor for leaks and corrosion Recycle to process if practical
Vacuum Systems	<ul style="list-style-type: none"> Waste discharge from jets 	<ul style="list-style-type: none"> Substitute mechanical vacuum pump Evaluate using process fluid for powering jet 	<ul style="list-style-type: none"> Monitor for air leaks Recycle condensate to process

Exhibit 19 (cont.): Modifications to Equipment Can Also Prevent Pollution			
Equipment	Potential Environment Problem	Possible Approach	
		Design Related	Operational Related
Valves	<ul style="list-style-type: none"> ▪ Fugitive emissions from leaks 	<ul style="list-style-type: none"> ▪ Bellow seals ▪ Reduce number where practical ▪ Special packing sets 	<ul style="list-style-type: none"> ▪ Stringent adherence to packing procedures
Vents	<ul style="list-style-type: none"> ▪ Release to environment 	<ul style="list-style-type: none"> ▪ Route to control or recovery device 	<ul style="list-style-type: none"> ▪ Monitor performance
Source: Chemical Manufacturers Association. <i>Designing Pollution Prevention into the Process, Research, Development and Engineering</i> .			

It is critical to emphasize that pollution prevention in the chemical industry is process specific and oftentimes constrained by site-specific considerations. As such, it is difficult to generalize about the relative merits of different pollution prevention strategies. The age, size, and purpose of the plant will influence the most effective pollution prevention strategy. Commodity chemical manufacturers redesign their processes infrequently so that redesign of the reaction process or equipment is unlikely in the short term. Here, operational changes are the most feasible response. Specialty chemical manufacturers are making a greater variety of chemicals and have more process and design flexibility. Incorporating changes at the earlier research and development phases may be possible for them.